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Hydrogeology of the Kananaskis Lake Area, Alberta

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ABSTRACT

The Kananaskis map area, in southwestern Alberta, falls within the Rocky Mountains, the Foothills, the Porcupine Hills and the Plains physiographic regions. The map area covers about 8500 km^2 (3300 sq mi). Mean annual total precipitation varies from 460 mm (18 in) in the Calgary area to over 1000 mm (40 in) in the Mountain areas. The quality of the groundwater is generally excellent. Total dissolved solids content of groundwaters varies from less than 50 mg/L to slightly over 1500 mg/L, but most groundwaters have a total dissolved solids content below 500 mg/L. Sodium bicarbonate and calcium-magnesium bicarbonate are the main chemical types and sulfate, chloride, and nitrate generally occur as minor anions. Total dissolved solids content increases towards the east.

Yields have a wide range (from 1 igpm to over 500 igpm) in this area and the Plains and Foothills regions show an especially great variation of yield. The wide range results from the differing lithologies of both the drift and the bedrock, and also from the presence of fracture systems, which are more developed in the Mountains and in the Foothills portions of the map area.

The Mountains appear to have a much different hydrogeological character than the other regions of the map area due to the presence of small, short flow systems. Because of the lack of data, the yields in the Mountains are not well known. Flow systems, in general, seem both short and shallow. Karst areas, which may produce extremely large yields, are found in the Mountains.

INTRODUCTION

The Kananaskis map area, in southwestern Alberta, lies between longitude 114° and the provincial boundary of British Columbia, and between latitudes 50° and 51° north. The area, approximately 8500 km^2 (3300 sq mi), can be divided into four physiographic units: the Rocky Mountains (42 percent of the map area) to the west, the Rocky Mountains Foothills (42 percent) in the centre, a Plains portion (18 percent) in the northeast, and the Porcupine Hills (about 2 percent) in the southeast corner of the map area.

The southwest portion of Calgary, which has a total population of 470 000 (Government of Alberta, 1977), is in the northeast corner of the map area. The more important small towns in the area are Black Diamond (pop. 1217), Turner Valley (pop. 823), and the village of Longview (pop. 189). Other small settlements include Bragg Creek, Priddis, Millarville, and Pekisko.

A large portion of the map area is not settled. Most of the population and cultivation are found in the small Plains region.

The area has two Indian reserves. The Sarcee Indian Reserve, about 280 km^2 (110 sq mi), straddles both the Kananaskis and the Calgary map areas and borders the western portion of Calgary. The Eden Valley Indian Reserve, in the Highwood River Valley, is about 30 km (20 mi) southwest of the village of Longview.

Good hunting and fishing are found nearly everywhere in the Mountains and in the Foothills regions. These regions serve as recreational areas for many people. Closer to Calgary, mainly in the Bragg Creek, Priddis and Black Diamond areas, new residential developments are taking place.

The Plains and Foothills areas suffer most from the pressure of development. In the Foothills, the main area being developed is near Bragg Creek, Priddis, and Millarville to the west and south-southwest of Calgary. In the Plains part of the map area, development is booming south and southwest of Calgary around Okotoks, Turner Valley, and Black Diamond. Pressure from development has not yet reached the Mountain areas, which are still in a virgin or near virgin state.

A small part of Banff National Park (340 km^2 or 130 sq mi) is in the northwest corner of the study area.

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TOPOGRAPHY AND DRAINAGE

Topographic elevations range from about 1100 m (3300 ft) in the vicinity of Calgary to slightly over 3600 m (11 800 ft) in the Mountains. Several peaks reach altitudes above 3300 m (10 000 ft) in the portion of the map area that borders the province of British Columbia. The highest peak, Mount Assiniboine, which has an elevation of 3617 m (11 870 ft), is located in the northwest corner of the map.

Several deep valleys in the Mountains are about 1.6 to 2.5 km (1 to 1.5 mi) wide: the valleys of Smith-Dorrien Creek, the Kananaskis River, the Highwood River, the Elbow River, and Livingstone Creek. Cars can cross the ranges over two main passes: the Highwood Pass along the Kananaskis road (100 km or 65 mi) west of the village of Longview, which reaches an elevation of slightly over 2200 m (7200 ft); and the Hailstone Butte Pass 16 km (10 mi) west of Chain Lakes, which reaches an elevation of 1900 m (6250 ft).

The northwestern portion of the Porcupine Hills is in the southeastern portion of the map area. The hills, a striking feature above the Plains landscape, reach a maximum elevation of 1800 m (5900 ft) in the southeastern corner of the map area. The hills slowly decrease in altitude towards the north; their northern edge is a few miles south of the hamlet of Pekisko.

A dense network of rivers, creeks, and streams blankets the map area. To the east in the Plains, rivers, creeks, and streams flow in a general west-east and southwest-northeast direction. The main streams are Priddis Creek, Three Point Creek, Sheep River, Highwood River, and Willow Creek. To the north of the map area, from its source in the Mountains, the Elbow River flows parallel to the Foothills.

The creeks and rivers in the Mountains run parallel to the main mountain ranges. In the northwestern portion of the map area, the water runs in a general southwest-northeast direction. The main streams found here are the Spray River and the Smith-Dorrien Creek that flows into the Kananaskis River which, in turn, flows from the Kananaskis Lakes in a northeasterly direction. All of these eventually empty into the Bow River drainage system. In the southern part of the map area, the main streams are the Oldman River and the Livingstone River, the latter originating in the Livingstone Range and draining into the large Oldman River drainage system.

Three large reservoirs are found in the map area: Spray Lakes Reservoir supplies hydroelectric power to the town of Canmore and the upper and lower Kananaskis Lakes supply hydroelectric power to other parts of the map area.

CLIMATE

According to Koeppen's climate classification (Longley, 1972), the Mountains and Foothills regions have a microthermal climate: the average temperature of the warmest month is above 10°C (50°F) and the average temperature of the coldest month is below −3°C (27°F). These areas have cool summers with the mean temperature of the warmest month below 23°C (72°F) and less than four months with mean temperatures of 10°C (50°F) or more. The Plains region, including parts of Calgary, has warm summers with the mean temperature of the warmest month below 23°C (72°F) and at least four months with mean temperatures of 10°C (50°F) or more. The Mountains and Foothills areas have 90 frost-free days; the northeastern portion of the map area (Calgary area) has 100 frost-free days.

Total precipitation varies from about 460 mm (18 in) in the Calgary region to over 1000 mm (40 in) in the Mountains. The boundary between the Foothills and the Mountains receives over 690 mm (27 in) of precipitation. For the area to the west, data are inadequate, since observations are made only during summer months at forestry lookout towers. For the Calgary region, 33 percent of the precipitation falls as snow; 42 percent at the Willow Creek station; and an unknown amount in the Mountain regions.

VEGETATION

Only 20 percent of the Kananaskis area has arable soil suitable for agriculture, mainly hay and coarse grain. The rougher terrain, at the higher elevations and in main river valleys, is used for grazing.

> "The native vegetation is characterized by a gradual change toward the west from prairie to mountainous vegetation. Natural tree growth occurs mainly in the foothills, where trembling aspen, balsam poplar, spruce and willow are common" (Canada Department of the Environment, 1971).

GEOLOGY

BEDROCK GEOLOGY

Various authors have studied and described the geology of the area: Hume (1931a, 1931b, 1931c, 1940, 1941, 1949), Hume and Beach (1942), Hume *et al.* (1942), Beach (1942), Hage (1946), Allan and Carr (1947), Douglas (1949, 1950, 1958), Norris (1958a, 1958b), Price (1962), Mellon (1967), Green (1970), Carrigy (1971).

Table 1 shows the general stratigraphy, rock types, and associated hydrogeological features of the Kananaskis map area.

The bedrock geology, from Green (1970), may be described as follows:

PROTEROZOIC: Miette Group: grey, pink, and green argillite; argillaceous sandstone, grit, conglomerate; minor dolomite, limestone, and shale.

PALEOZOIC: Gog Group: thick-bedded, grey, pink, and purple quartzite and quartzose sandstone, with shale and limestone lentils.

Middle and Upper Cambrian: pale grey, thick-bedded dolomite and limestone; dark grey, fine-grained, thick- to thin-bedded limestone and dolomite; maroon, buff, and green calcareous and siliceous shales; local intraformational conglomerates.

Ordovician: grey to grey-green limestone, shaly limestone and shale, local intraformational conglomerate; pale grey to pale brown, medium-bedded, siliceous dolomite; clean white quartzite.

Upper Devonian: grey argillaceous limestone and dolomite, in party cherty and stromatoporoidal, in part coarsely biostromal; black nodular and calcareous shale; grey to brown aphanitic to finely crystalline limestone, dolomite-mottled limestone, and dolomite; black bituminous shale.

Mississippian: dark grey fissile shale, siltstone, agrillaceous limestone and cherty limestone; medium- to coarse-grained crinoidal limestone, cherty and dolomitic limestone; dolomite, cherty dolomite, anhydrite, red shale, and sandstone.

Pennsylvanian-Permian: thin- and thick-bedded quartzite sandstone, phosphatic quartzose siltstone, silty and cherty dolomite, chert and cherty carbonate.

TABLE 1. Stratigraphy, rock types and hydrogeological features of the Kananaskis map area.

ERA	PERIOD	EPOCH	SYMBOL	ROCK TYPES	HYDROGEOLOGICAL FEATURES
CENOZOIC	QUATERNARY		Qd	River sand and gravel, soil, glacial deposits, alluvium, colluvium etc...	Springs up to 7.6 1/sec (100 igpm) High yields in river valley gravels (Black Diamond) Water types from CaHCO3 to NaHCO3
	TERTIARY	PORCUPINE HILLS & PASKAPOO FORMATIONS	Tp Tkp	Nonmarine sandstone and shale	Many springs in Porcupine Hills. Discharge up to 3.8 1/sec (50 igpm) Water type CaMgHCO3
MESOZOIC	CRETACEOUS — UPPER	WILLOW CREEK FM	Tkw	Sandstone	Aquifer yield in the order of .07 to .4 1/sec (1 to 5 igpm)
		BRAZEAU FM — ST. MARY-EDM. FM	Khc	Nonmarine shale and sandstone with coal	
		BRAZEAU FM — BEARPAW FM	Kbp	Marine shale	
		BRAZEAU FM — BELLY RIVER FM	Kbr	Nonmarine shale and sandstone	
		ALBERTA GP — WAPIABI FM	Kwb (Ka)	Marine shale and sandstone	Yields from .07 to .4 1/sec (1 to 5 igpm) Possibly higher yields where fracturing occurs Water type Na2SO4
		ALBERTA GP — CARDIUM FM	Kcr (Ka)		
		ALBERTA GP — BLACKSTONE FM	Kbk (Ka)		
	CRETACEOUS — LOWER	BLAIRMORE GP	Kbl (Mz)	Nonmarine sandstone and shale Coal bearing Luscar Formation	NO DATA
		BLAIRMORE GP — LUSCAR FM			
		KOOTENAY FM		Nonmarine sandstone and shale with coal	Springs from coal at high elevation (2400 m or 8000 ft), depositing iron in talus; Storm Creek Springs (see text) CaHCO3 water type
	JURASSIC	NIKANASSIN FM		Nonmarine sandstone and shale	
		FERNIE FM		Marine shale	
	TRIASSIC				NO DATA
		SPRAY RIVER FM		Dolomitic siltstone and shale, dolomite, limestone	
	PERMIAN	ROCKY MOUNTAIN GP	Pzu	Quartzite, dolomite, siltstone, chert	KARST DEVELOPMENT: Canyon Creek karst spring (see text) H2S, sulfur bacteria colonies, elemental sulfur in suspension in ponds Discharge 76 1/sec (1000 igpm) Water type CaHCO3 Canyon Creek Ice cave Plateau Mountain ice cave Misty Range springs
	PENNSYLVANIAN				
	MISSISSIPPIAN	RUNDLE GP		Limestone, dolomite	
		BANFF FM		Calcareous shale, limestone	
PALEOZOIC	DEVONIAN	PALLISER FM		Limestone	
		ALEXO FM		Silty dolomite and limestone	
		FAIRHOLME GP		Dolomite, limestone	
	ORDOVICIAN		Pzl	Limestone, shale, quartzite	NO DATA
	CAMBRIAN			Dolomite, limestone, shale	
		GOG GP	Є	Quartzite	
PRECAMBRIAN		PURCELL & MIETTE GROUPS	Єm Єp	Argillites, quartzites, carbonates	

Sources of information:

Energy Resources Conservation Board (1973): Table of Formations, Alberta.

Geology of Alberta Rocky Mountains and Foothills (1974); Alberta Research Council map, compiled by M. E. Holter and I. J. McLaws, 1972, from published maps of the Geological Survey of Canada and the Alberta Society of Petroleum Geologists.

MESOZOIC:

Triassic: dark grey to black siltstone; dolomitic siltstone and limestone; silty dolomite, limestone, breccia, and gypsum.

Jurassic: dark grey to black fissile shale and siltstone; black cherty and phosphatic dolomite and limestone; green glauconitic shale and sandstone.

CRETACEOUS:

Nikanassin and Kootenay Formations: thick-bedded, fine- to coarse-grained cherty sandstone interbedded with dark grey shale, siltstone, and coal.

Blairmore Group: grey, siliceous, calcareous sandstone; green chloritic and feldspathic sandstone; dark grey carbonaceous and calcareous shale; grey, green, and red shale and silty shale; some conglomerate coal; trachytic tuff, agglomerate.

Alberta Group: dark grey fissile, silty shale, thick-bedded, well-sorted quartzose sandstone, dark grey shale and carbonaceous shale; siltstone and coal beds (Cardium), siltstones and glauconitic sandstone, concretionary ironstone.

Belly River Formation: grey to greenish-grey, thick-bedded, feldspathic sandstone; grey clayey siltstone, grey and green mudstone; concretionary iron beds; nonmarine.

Bearpaw Formation: dark grey blocky shale and silty shale; greenish glauconitic and grey clayey sandstone; thin concretionary ironstone and bentonite beds; marine.

Horseshoe Canyon Formation: grey, feldspathic, clayey sandstone; grey bentonitic mudstone and carbonaceous shale; concretionary ironstone beds, scattered coal and bentonite beds of variable thickness, minor limestone beds; mainly nonmarine.

CENOZOIC:

Willow Creek Formation: pale grey, fine-grained, calcareous sandstone, thick-bedded and coarse-grained in upper part, grey, green, and pink bentonite mudstone with abundant white weathering calcareous concretions, scattered thin limestone beds; nonmarine.

Porcupine Hills Formation: pale grey, thick-bedded, cherty calcareous sandstone, pale grey calcareous mudstone; nonmarine.

The geological side map, from Green (1970), generalizes the geology of the area. To keep it simple, thrust faulting, although common in the area, has not been indicated on the geology map. Several geological boundaries are fault contacts. The main thrust faults drawn schematically appear on the cross sections.

Karst phenomena are found in the Canyon Creek valley where karst springs, issuing from limestones of the Banff Formation, and several caves in Paleozoic limestones have been found (Ford, 1973). In the south-central part of the map area, another cave is situated in the Plateau Mountain area in limestones of the Banff Formation of Mississippian age.

BEDROCK TOPOGRAPHY AND DRIFT THICKNESS

A bedrock topography map was constructed for the eastern part of the map area where some seismic shothole information and water-well lithologs were available. The thickness of the surficial sediments and intervals of sands and gravels thicker than 3 m (10 ft) were then outlined.

The bedrock topography is very similar to the land surface topography except in the main river valleys where thick surficial sediments were deposited. Thick surficial sediments, 30 to 60 m (100 to 200 ft), are found in the extreme northeast corner of the map area in the Bow River bedrock channel, part of which is found within the Calgary city limits.

Well-developed sand and gravel terraces can be seen in the Highwood River valley southwest of the village of Longview.

Valley fills of the main mountain valleys such as the Smith-Dorrien Creek, Kananaskis River, and parts of the Highwood and Sheep River valleys may prove to be a large source of groundwater.

HYDROGEOLOGY

PREVIOUS WORK

Stevenson (in preparation) studied the Marmot Creek and Streeter basins from 1967 to 1968. Meyboom (1961) investigated the groundwater resources of Calgary. Several private consultants' reports deal with water supplies in the Bragg Creek, Priddis, and Black Diamond areas.

AREAS OF FLOWING WELLS

Areas of flowing wells have been outlined on the main map and occur in the Mountains, Foothills, and Plains regions of the area. These areas are most concentrated in the Foothills in a band parallel to the Mountains. Flowing wells, as well as flowing shotholes found in the area, are rarely deeper than 30 m (100 ft), indicating shallow upward groundwater movement, since deeper wells do not flow. These large areas of shallow upward movement of groundwater could result from local confinement by tills. Flowing rates of these wells generally range from less than 0.07 to 0.4 L/s (1 to 5 igpm), although most flow at 0.07 L/s or less. These wells indicate a wide and long zone of discharge that produces very little water, which may indicate poor recharge conditions or the presence of rocks of low permeability. In the map area, 416 flowing wells and flowing shotholes have been recorded, only 12 percent of those are used by farmers for water supplies.

WATER LEVELS

Two sets of water levels for drift and bedrock aquifers were constructed for the eastern portion of the map area where water level data are concentrated. In the bedrock, wells range from about 7 to 155 m (24 to 510 ft) deep, the average depth being about 45 m (150 ft). In bedrock aquifers, nonpumping water levels are fairly deep, as, for example, in the area of Black Diamond. Nonpumping water levels in the surficial sediments are usually fairly shallow, much shallower than in the bedrock, suggesting a downward movement of groundwater from surficial sediments into bedrock sediments. In both the drift and the bedrock sediments, water level trends show the influence of the surface topography, and, therefore, groundwater movement is towards streams and rivers. The drift aquifers, however, show small local exceptions. In portions of the Sarcee Indian Reserve area southwest of Calgary, groundwater flows very locally away from a tributary of Fish Creek; farther east the same conditions occur in the vicinity of Fish Creek itself at the southeast corner of the Sarcee Indian Reserve. In these two cases, the influent streams recharge local surficial aquifers.

In the Mountain regions, water levels are deep and gradients steep. Perched water table conditions in the Marmot Creek basin in the northwestern part of the map area are described by Stevenson (in preparation).

SPRINGS

Springs are a common feature of the Mountains and Foothills regions of Alberta (Borneuf, in preparation). The main hydrogeological maps show the main springs found during the 1975 field season. In general, smaller springs are found in the Plains region and some of these are used for domestic water supplies.

One large and spectacular spring site visited during the 1975 field season is located in the Canyon Creek valley west of the village of Bragg Creek. This group of karst springs, with an estimated discharge of 75 L/s (1000 igpm), discharges at several locations over a large area. Hydrogen sulfide gas bubbles up locally, and large sulfur bacteria colonies are common. Iron sulfide and elemental sulfur in suspension are also common in the spring waters. A short distance downstream from the spring site the water reinfiltrates through the Canyon Creek bed sediments and deposits iron in the boulders in the creek bed. This group of springs, near the fold axis of an anticline in Devonian, Mississippian, and Pennsylvanian rocks, probably issue from fractures in the limestones of the Banff Formation of Lower Mississippian age.

An interesting feature of the area one-half mile northwest of the spring site is an ice cave (see Ford, 1973) about 190 m (600 ft) above the Canyon Creek valley floor in Paleozoic rocks. The spectacular ice pillars near the entrance of the cave are one site that attracts visitors to the area. The ice cave has, unfortunately, suffered degradation. Another ice cave, the Plateau Mountain ice cave, is in the south-central part of the map area. In order to protect the beautiful hexagonal ice crystals found in it, the cave is now closed to most visitors.

A medium-sized spring a few miles south of the village of Bragg Creek, which flows at about 42 L/s (500 igpm) (Tokarsky, pers. comm.), is used for recreational purposes by the Bar K.C. Club. Water from a 2 to 3 m (9 to 10 ft) deep pool about 10 m (30 ft) in diameter is diverted from there to various areas of the ranch. To the southeast of this spring, a smaller spring provides water to a barn.

In the Storm Creek valley in the south-central part of the map area, three springs were observed at high elevations (above 2130 m or 7000 ft). Water issuing from these springs reinfiltrates the talus at lower elevations and reappears at several spring locations where heavy iron deposits can be seen. This type of spring, found at other locations in the map area, has been observed in other parts of the Mountains.

Numerous smaller springs are found in the portion of the Porcupine Hills, which lie in the southeastern portion of the map area, and a large number of springs have been observed on the eastern slopes of those hills by Ozoray (1974). Most of these springs are discharge points for perched aquifers in the Porcupine Hills Formation (Stevenson, pers. comm.).

TEST DRILLING

Three testholes were drilled during the 1975 field season. Site No. 1 tested aquifers in a suggested groundwater discharge area and determined the thickness and permeability of the surficial deposits. In addition to surficial material, site No. 2 also tested the bedrock. Site No. 3 determined the thickness and hydraulic characteristics of the alluvium. The Appendix contains the lithologs of the testholes.

Testhole Number 1: Lsd 9, Sec 8, Tp 17, R 2, W 5th Mer

This hole, drilled to 152 m (500 ft), encountered 8 m (25 ft) of till, and bedrock sediments of alternating black carbonaceous shales and fine-grained, light grey hard sandstones. After development, the interval from 13 m (43 ft) to 152 m (500 ft) was pump tested at 0.12 L/s. (1.6 igpm). The transmissivity was 3.2 igpd/ft. No water was found in the first 8 m (25 ft) of surficial sediments.

Testhole Number 2: Lsd 1, Sec 22, Tp 14, R 2, W 5th Mer

This testhole, drilled to 152 m (499 ft), had 6 m (19 ft) of sandy clay; bedrock was mainly composed of black shale alternating with fine-grained hard to medium-hard sandstones. Water was found in the hole at 12 m (39 ft) and the intervals from 5.5 m (18 ft) to 32 m (105 ft) was pump tested in an open hole configuration. A 10-hour pump test, with 6 hours of drawdown and 4 hours of recovery, was conducted.

Two transmissivity values were obtained: for the early part of the drawdown curve, the transmissivity was 410 igpd/ft; for the later part of the drawdown curve, the transmissivity was 250 igpd/ft. The 20-year safe yields calculated were 0.9 and 0.6 L/s (13 and 8 igpm) — the latter being closest to the true value. In another pump test (6.5 hours), conducted using an open-hole completion between 18 m (61 ft) and 152 m (499 ft), the transmissivity for the latest portion of the drawdown curve was 137 igpd/ft, indicating a 20-year safe yield of 0.75 L/s (10 igpm).

Testhole Number 3: Lsd 5, Sec 30, Tp 16, R 3, W 5th Mer

This testhole, in the Pekisko Creek valley, encountered 18 m (58 ft) of surficial sediments composed mainly of sands, gravels, and boulders, with minor amounts of clay. A 4-hour pump test (2 hours of drawdown and 2 hours of recovery) indicated that the transmissivity of the interval pumped (9 to 14 m or 30 to 45 ft) is 1075 igpd/ft and the 20-year safe yield is 1.2 L/s (17 igpm). The remainder of the testhole from 18 m (58 ft) to 130 m (425 ft), mainly composed of fine-grained, pale grey, hard sandstone and alternating black shales, was not tested.

YIELDS

All yield categories, except one (>38 L/s or 500 igpm), are represented over the map area. Data on yield density are very good in the north-eastern portion of the map area and poor to nonexistent in the Foothills and Mountain areas. Most yield values come from either short bail tests or 2-hour pump tests. Longer pump tests are the exception, which explains the choice of pale colors (meaning possible rather than probable yield values) over most of the map area. In the Mountains, sediments above 2100 m (7000 ft) were arbitrarily assigned a yield value of less than 0.07 L/s (<1 igpm). Field observations suggest that most sediments above that elevation are generally unsaturated. Gradients are steep and surficial deposits are absent or very thin. Perched aquifers may, however, be present locally as in Marmot Creek basin (Stevenson, in preparation), Storm Creek, and Misty Range. The possible yields of these perched aquifers remains small. In the Mountains and in the Foothills, pump tests were unavailable and yield ranges were assigned using field observations, the lithologies of the sediments present in these areas, and the topography. The main mountain valleys, such as the Highwood River, Storm Creek, Pocaterra Creek, Smith-Dorrien Creek, Spray River, and Kananaskis River valleys, may contain good groundwater potential in the alluvial and colluvial sediments. The springs in the Mountains and those in the Foothills probably indicate the magnitudes of possible yields in various formations.

In general, the main yield range in the map area is 0.07 to 0.38 L/s (1 to 5 ipgm). This general yield value is modified locally by the presence of higher permeabilities, which are the result of fractures, dissolution channels in carbonates, or the presence of sands and gravels.

The highest yields found in the map area are between 7.6 and 38 L/s (100 and 500 igpm), and are found in the northeast corner of the map area in the sands and gravels of the Bow River bedrock channel in the immediate vicinity of Calgary. Portions of the carbonate rocks in the Mountains, such as the limestones of the Banff Formation near Canyon Creek Spring, may possibly produce yields of the same magnitude.

Local areas have yields of 1.9 to 7.6 L/s (25 to 100 igpm). This range of yield values can result from local fracturing in bedrock sediments and the presence of alluvial sands and gravels, as in the case of the Sheep and Highwood River valleys. If sands and gravels are well developed, as in the Highwood River valley upstream from the village of Longview or in the Black Diamond area, yields could range from 7.6 to 38 L/s (100 to 500 igpm).

In the Rocky Mountains, the alluvial and colluvial sediments of the main valleys have been conservatively assigned the yield range of 2 to 7.6 L/s (25 to 100 igpm) based on the few, short, pump tests available.

HYDROCHEMISTRY

The hydrochemical side map on the main map represents only the eastern part of the map area where data were adequate. For the area not covered by the map, including the Mountains and the western part of the Foothills, several generalizations can be made. The quality of the groundwater is excellent everywhere and the total dissolved solids content of the groundwaters in this area is below 500 mg/L in most instances. Groundwaters are generally of the calcium-magnesium bicarbonate type and are typical of areas of recharge and of short flow systems. Calcium-magnesium sulfate or sodium-sulfate types of water are occasionally found in areas of shales and in some discharge areas. Slow groundwater movement may be responsible for locally high total dissolved solids.

DRIFT WATERS IN THE EASTERN PART OF THE MAP AREA

The total dissolved solids of groundwaters in the drift are usually low, ranging from less than 300 mg/L to slightly over 1200 mg/L, with higher total dissolved solids values found in discharge areas. The groundwaters are usually a calcium-bicarbonate type, except for minor occurrences of a sodium-bicarbonate type and of a sodium-sulfate type at the eastern boundary of the map area. The latter two chemical types are found together with thin salt deposits in the eastern part of the map area only and are probably related to slow groundwater movement and discharge. Sodium-bicarbonate and sodium-sulfate chemical types of groundwater are found a few miles to the west of the town of Okotoks and along the road from Chain

Lakes to Nanton, where groundwater seeps through shales over large areas. In these large seepage areas, the slopes are unstable and erosion is common.

BEDROCK WATERS IN THE EASTERN PART OF THE MAP AREA

Total dissolved solids of bedrock waters, which are slightly higher than drift waters, exceed 1000 mg/L in only a few areas; the average value is about 500 mg/L. Bedrock waters are of a calcium-magnesium bicarbonate type except for minor occurrences of a calcium-magnesium sulfate type and a sodium-sulfate type along the eastern border of the map area.

CONCLUSIONS

The groundwater potential is fair to excellent over the map area. The Mountains and the Foothills areas may prove to have better potential than that indicated in the main map, especially in the main mountain valleys. The Plains area, containing most of the population, has poor to excellent groundwater potential with 0.07 to 0.38 L/s (1 to 5 igpm) nearly everywhere and locally, sands and gravels found in the main valleys may possibly provide up to 38 L/s (500 igpm).

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APPENDIX.
ALBERTA RESEARCH COUNCIL TESTHOLES

PEKISKO NUMBER 1: Lsd 9, Sec 8, Tp 17, R 2, W 5th Mer

Depth (feet)	Lithology
0 - 25	Till, light brown, clayey, sandy, pebbles
25 - 67.5	Shale, black, carbonaceous; minor sandstone, grey, fine-grained
67.5 - 75	Sandstone, grey, fine-grained, medium hard
75 - 101.25	Shale, black, medium hard; stringers of sandstone, grey, fine-grained, medium hard
101.25-123.75	Sandstone, grey, fine-grained, medium hard
123.75-135	Shale, dark brown, carbonaceous, medium hard
135 - 150	Sandstone, light grey, fine-grained, soft
150 - 172.5	Shale, black, hard; minor sandstone, light grey, soft
172.5 - 187.5	Sandstone, light grey, fine-grained, soft; minor siltstone, hard, and shale, black
187.5 - 198.75	Shale, black, hard; stringers of sandstone, light grey, fine-grained, soft
198.75-210	Sandstone, light grey, fine-grained, hard
210 - 215	Shale, black, hard
215 - 225	Sandstone, light grey, fine-grained, medium hard, in shale, black
225 - 230	Shale, black, hard
230 255	Sandstone, light to dark grey, fine-grained, soft to hard
255 - 300	Shale, black, medium hard to hard, minor siltstone and sandstone, pale grey, medium hard to hard
300 - 325	Sandstone, light to dark grey, fine-grained, white specks at 300-325
325 - 350	Shale, black, medium hard to soft
350 - 415	Sandstone, light grey, fine-grained, soft, clayey, medium hard to very hard; some shale, black, medium hard to hard
415 - 475	Shale, dark brown, carbonaceous, soft; coal, minor siltstone and sandstone, pale grey, hard to medium hard
475 - 505	Shale, dark brown, carbonaceous; minor coal

CHAIN LAKES NUMBER 2: Lsd 1, Sec 22, Tp 14, R 2, W 5th Mer

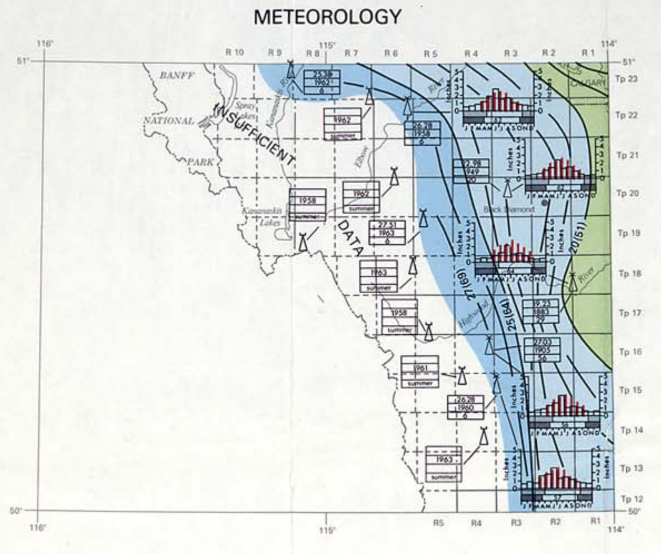
Depth (feet)	Lithology
0 - 17	Clay, sandy, brown, soft
17 - 19	Shale, light grey, hard
19 - 27	Sandstone, light grey, medium-grained, hard, fractured, water-bearing
27 - 35	Shale, black to grey, iron-staining, hard
35 - 40	Sandstone, light grey, fine, hard
40 - 65	Shale, black, hard; stringers of sandstone, medium-grained, clayey, soft
65 - 85	Sandstone, pale grey, medium hard; stringers of shale, black, medium hard
85 - 105	Shale, greyish black, medium hard
105 - 135	Sandstone, pale grey, medium-grained, medium hard
135 - 160	Mixture of sandstone, light grey, fine, medium hard, and shale, pale to dark grey, sandy
160 - 205	Sandstone, light grey, medium hard to very hard
205 - 215	Mixture of sandstone, light grey, fine-grained, medium hard, and shale, medium grey, hard
215 - 300	Sandstone, light grey, fine-grained, medium hard to hard; a little shale, dark grey, iron-stained, medium hard; a little siltstone, light grey, very hard
425 - 470	Mostly sandstone, brownish-grey, fine-grained, medium hard to very hard; layers of shale, black, medium hard
470 - 499	Mostly siltstone, greenish dark grey, hard; sandstone, dark grey, fine-grained, medium hard

CARTWRIGHT NUMBER 3: Lsd 5, Sec 30, Tp 16, R 3, W 5th Mer

Depth (feet)	Lithology
0 - 1.5	Top soil, black, very fine
1.5 - 58	Mixture of gravel, pebbles, boulders, with clay and sand
58 - 87	Shale, black hard
87 - 260	Mostly sandstone, pale to dark grey, medium hard to very hard, fine- to medium-grained; minor amount of shale, brownish, medium hard
260 - 270	Alternating layers of sandstone, pale grey, fine-grained, soft, and shale, black, medium hard
270 - 280	Shale, black, medium hard
280 - 305	Alternating layers of sandstone, dark grey, hard, fine-grained, and shale, dark grey, medium hard
305 - 315	Shale, brownish to dark grey, medium hard
315 - 425	Alternating succession of shale, black, hard and sandstone, dark grey, fine-grained, soft to hard, and minor amounts of siltstone and coal.

Alberta
RESEARCH COUNCIL

METEOROLOGY



LEGEND

Isohyet, mean annual precipitation in inches (cm) .... 20(51)
Mean annual precipitation in inches (cm):
15 to 20 inches (38 to 51 cm):
20 to 25 inches (51 to 63 cm):
25 to 30 inches (63 to 76 cm):
Meteorological station ....
Standard rain gauge only ....
Precipitation data:
Mean annual precipitation estimated in inches ....
Year of commencement of observations ....
Number of years in average ....
Season of record if not yearly ....
Mean monthly potential evapotranspiration ....
Mean monthly precipitation ....
Period when surface is usually snow-covered ....
Period with mean daily temperatures below freezing ....
Figure indicates percentage of mean annual precipitation falling as rain ....

Source: Environment Canada

MAIN MAP LEGEND

Topography

Surface contours and elevation in feet (interval 500 feet) ....

Geology

Geological boundary ....
Buried valley boundary ....
Thalweg of buried valley:
defined: ....
approximate ....

QUATERNARY
- Qd Unconsolidated deposits
- Qa Alluvium
- Qc Colluvium

TERTIARY
- Tp Porcupine Hills Formation

TERTIARY-CRETACEOUS
- TKp Paskapoo Formation
- TKw Willow Creek Formation
- TKb Brazeau Formation

CRETACEOUS
- Khc Horseshoe Canyon Formation
- Kbp Bearpaw Formation
- Kbr Belly River Formation
- Ka Alberta Group

MESOZOIC
- Mz Undifferentiated Lower Cretaceous, Jurassic, and Triassic Strata

PALEOZOIC
- Pzl Undifferentiated Lower Paleozoic Strata

Lithology

Gravel ....
Sand and gravel ....
Sand ....
Sandstone ....
Silt ....
Siltstone ....
Shale ....
Conglomerate ....
Limestone ....
Dolomite ....

Hydrography

Lake or slough, perennial ....
Marsh, muskeg ....
Stream perennial ....
Stream, intermittent ....
Surface water divide ....
Area of noticeable salt precipitates ....

Hydrogeology

Spring, flow rate unknown ....
Spring, flow rate in igpm (L/sec) 10 (1)
Nonpumping water level contour in the drift (elevation in feet followed by metres in brackets) and vertical component of groundwater movement .... Upward flow 1900 (580) Downward flow
Groundwater divide ....
Boundary of area of artesian flow ....

Groundwater Probability†

Range of average expected yield of wells in imperial gallons per minute (L/sec)

Probable: estimated from quantitative information (pump tests, bail tests, etc.)
Possible: estimated from qualitative information (flow regime, lithology, etc.)

more than 500	(>38)
100-500	(8-38)
25-100	(2-8)
5-25	(0.4-2)
1-5	(0.1-0.4)
<1	(<0.1)

Yield area boundary ....

† The indicated average expected yields to wells are predictions based on the best data available at the time of map compilation, due to data shortcomings and special conditions, local discrepancies between predicted and actual yields are inevitable. Multaquifer completion may be necessary to obtain the yield indicated.

Wells and Other Artificial Works

Depth Scale — FEET 0, 100, 200, 300, 400 — Depth to water; Depth of well or seismic shot hole

Water well, nonflowing ....
Water well, flowing ....
Alberta Research Council test well .... ARC
Water well, 20-year safe yield calculated from apparent transmissivity ....
Water well, 20-year safe yield calculated from a good bail test or a short pump test ....
Water well, 20-year safe yield calculated from a pump test of sufficient length to reflect regional hydraulic conditions ....
Adjacent wells ....
Seismic shothole reported to have flowed ....
Oil well ....
Depth of exploratory well ....

*The vertical line portion of oil, gas, or other exploratory test well symbols indicates the well depth; the dashed portion indicates the surface casing interval where available or where known; otherwise a solid line is used.

Spring catchment ....
Line of hydrogeological profile .... A A′

Hydrochemistry

Calcium, Magnesium, Sodium + potassium (Cations) | Carbonate + bicarbonate, Sulfate, Chloride, Nitrate (Anions) — 0, 50%, 100%

Note: When the yellow Mg pie sector is absent, Ca + Mg are represented as a unit by the red pie sector.

Total dissolved solids in parts per million:
approximate 500

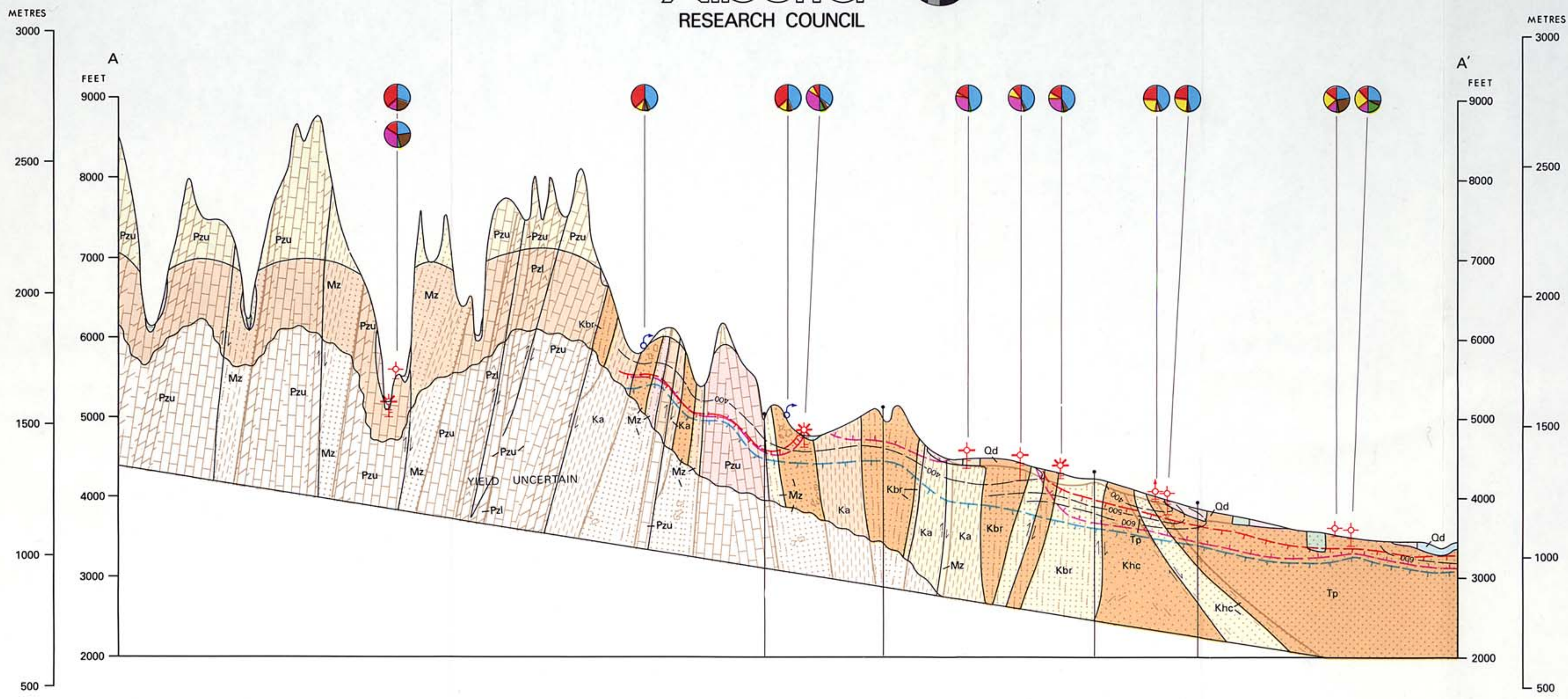
Isogram along which calcium + magnesium constitute 60 percent of total cations*; teeth indicate direction of lesser calcium + magnesium content:
approximate: ....

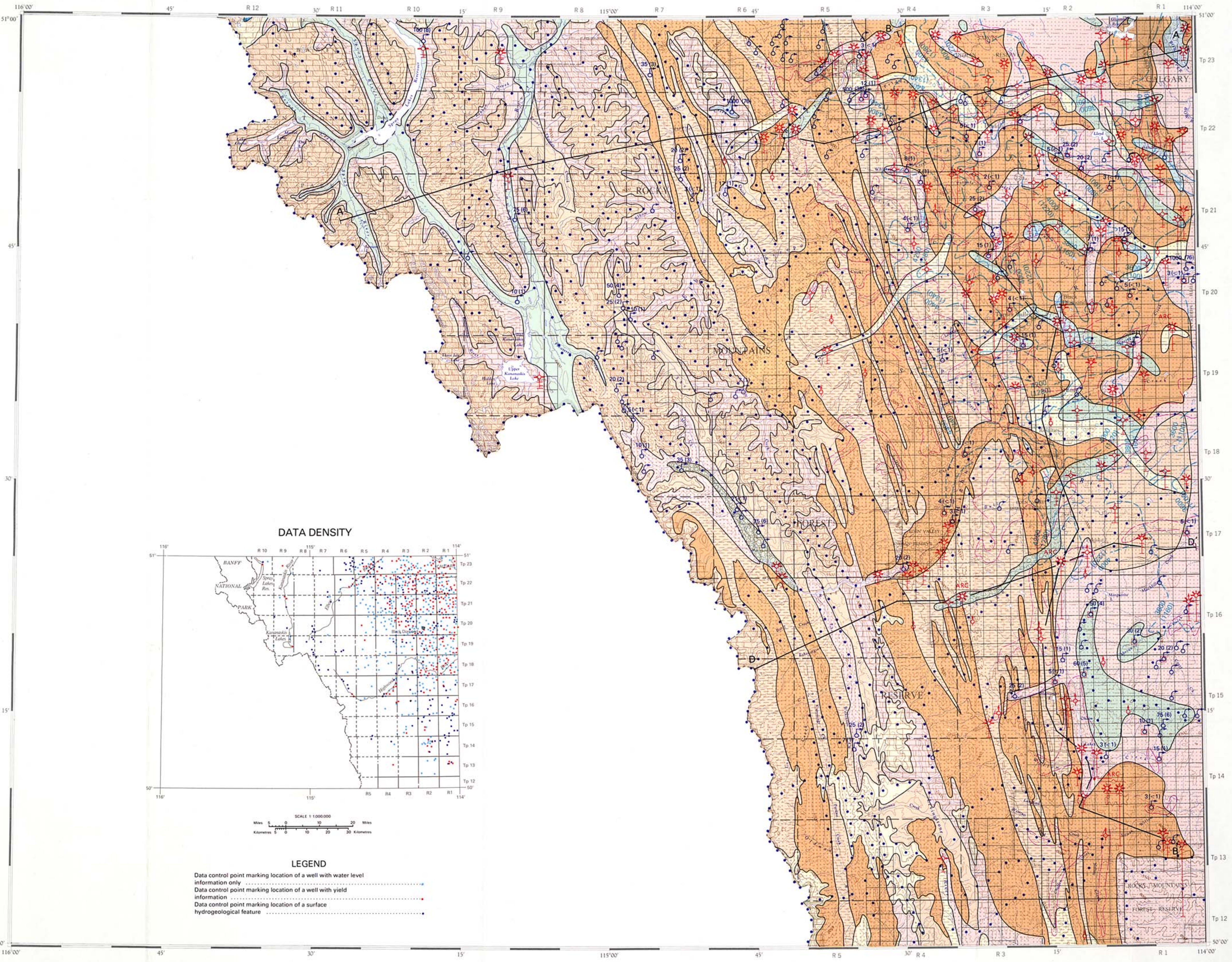
Isogram along which sodium + potassium constitute 60 percent of total cations*; teeth indicate direction of lesser sodium + potassium content:
approximate: ....

Isogram along which carbonate + bicarbonate constitute 60 percent of total anions*; teeth indicate direction of lesser carbonate + bicarbonate content:
approximate: ....

Isogram along which sulfate constitutes 60 percent of total anions*; teeth indicate direction of lesser sulfate content:
approximate: ....

* determined on equivalents per million basis





DATA DENSITY

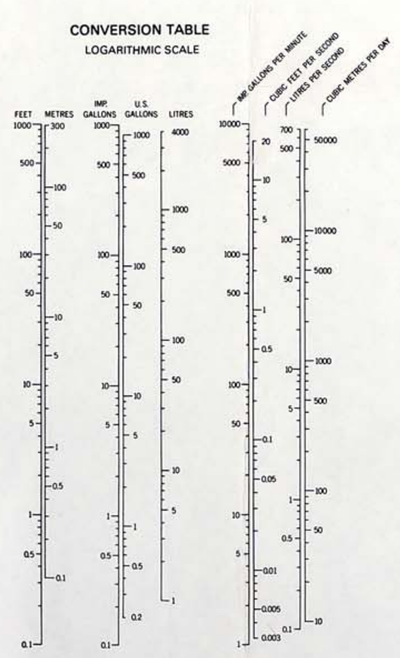
SCALE 1:1,000,000

LEGEND

Data control point marking location of a well with water level information only ....
Data control point marking location of a well with yield information ....
Data control point marking location of a surface hydrogeological feature ....

SCALE 1:250,000
Miles 5 0 5 10 15 20 Miles
Kilometres 5 0 5 10 15 20 25 30 Kilometres

CONVERSION TABLE
LOGARITHMIC SCALE



HYDROGEOLOGICAL MAP KANANASKIS LAKES ALBERTA

NTS 82J

All elevations in feet above mean sea level.

Vertical exaggeration of the hydrogeological profiles is approximately 40X.

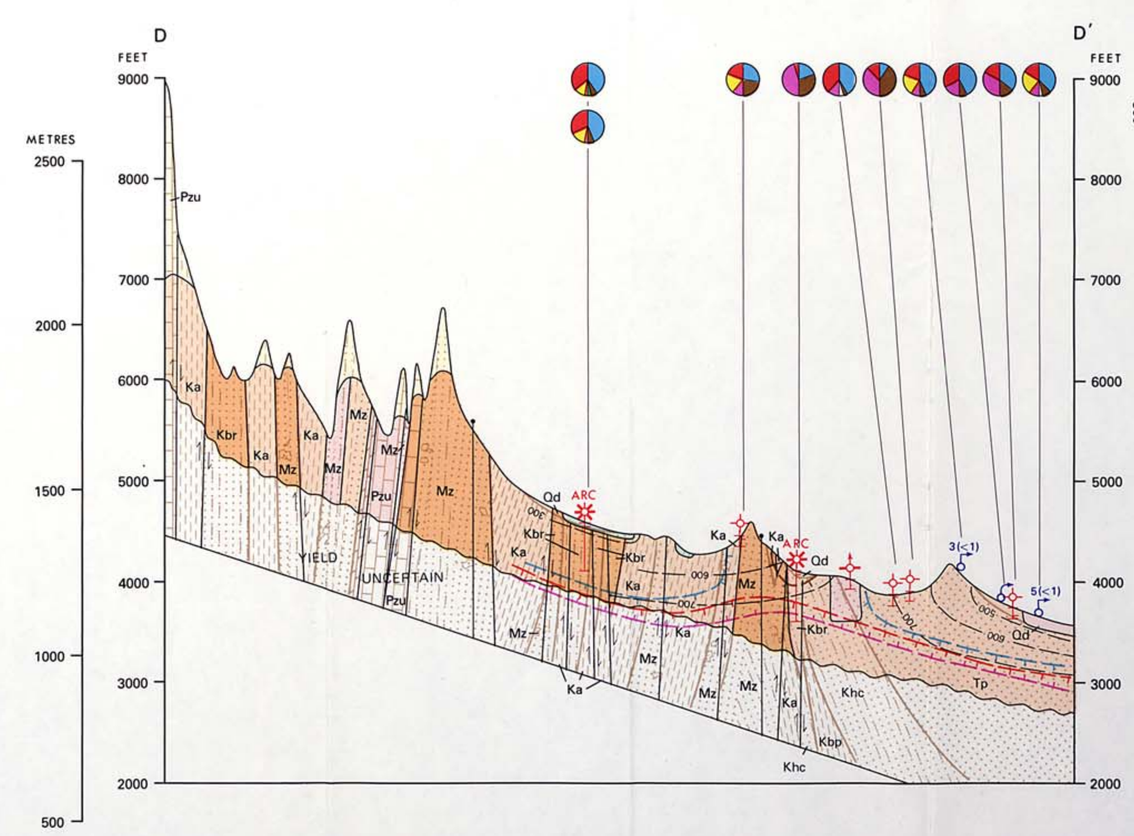
An expanded legend and explanatory notes (Report 72-12) for use with this hydrogeological map series is available from Publications, Alberta Research Council, 11315 - 87 Avenue, Edmonton, Canada T6G 2C2.

Map to accompany Report 79-4.

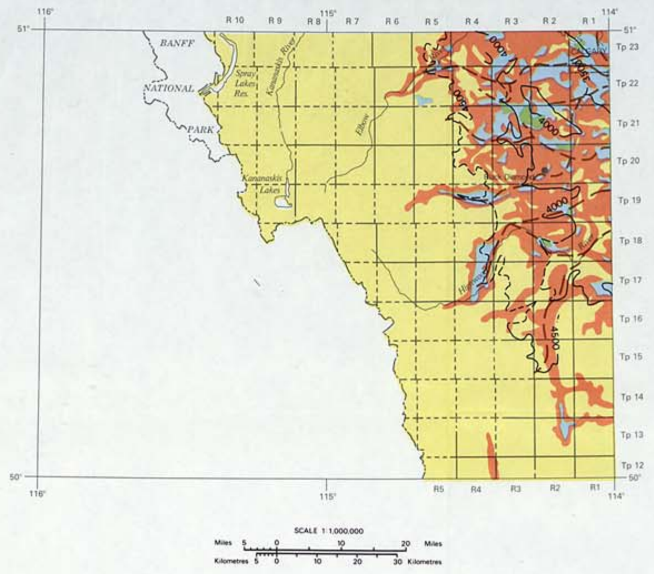
Hydrogeology by D. Borneuf.

Drafted by R.W. Swenson.

KEY MAP



BEDROCK TOPOGRAPHY AND DRIFT THICKNESS



SCALE 1:1,000,000

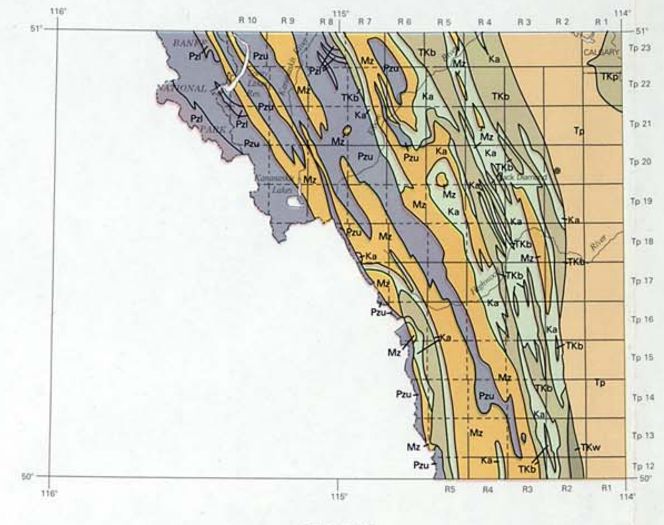
LEGEND

Bedrock contours:
defined: 3000
approximate 3000
Thickness of drift in feet (metres)

0 - 20	(0 - 6)
20 - 50	(6 - 15)
50 - 100	(15 - 30)
More than 100	(more than 30)

Thalwegs of bedrock channel ....

GEOLOGY



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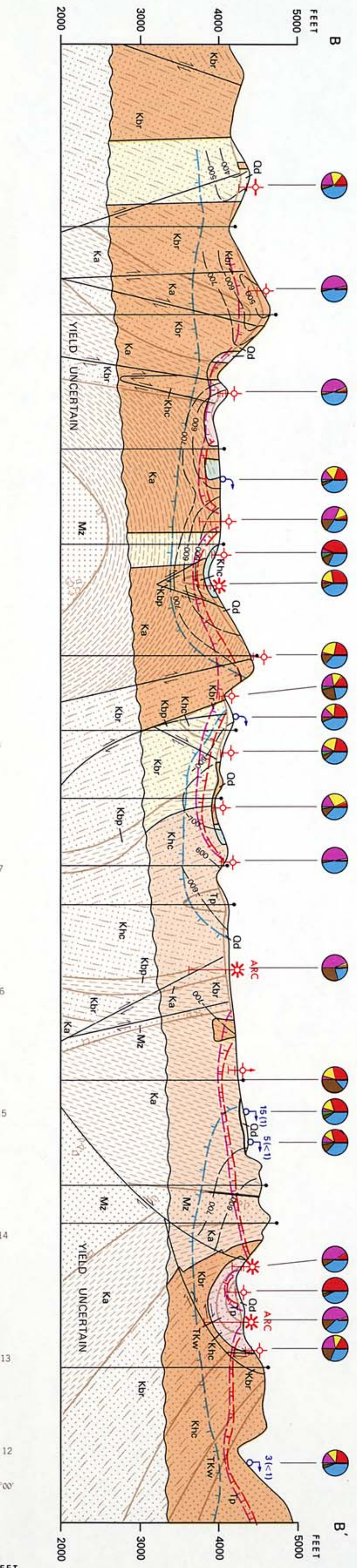


LEGEND

Porcupine Hills Formation: *thick-bedded, cherty, calcareous sandstone; mudstone; nonmarine* (Tp)

Paskapoo Formation: *thick-bedded, calcareous, cherty sandstone; siltstone and mudstone; minor conglomerate, limestone, coal and tuft beds; nonmarine* (TKp)

Willow Creek Formation: *fine-grained, calcareous sandstone, bentonitic mudstone with white-weathering calcareous concretions; scattered thin limestone beds; nonmarine* (TKw)

Brazeau Formation: *thick-bedded, chloritic and feldspathic sandstone and blocky gray mudstone; some tuff and thin coal beds; nonmarine* (TKb)

Alberta Group: *fissile, silty shale; some thin-bedded, fine- to medium-grained, cherty sandstone (Blackstone Formation) – thick-bedded, well-sorted, quartzose sandstone; shale and carbonaceous shale; siltstone and thin coal beds (Cardium Formation) – dark grey fissile shale and siltstone; thin-bedded, fine-grained, glauconitic sandstone; thin beds of concretionary ironstone (Wapiabi Formation).* (Ka)

Undifferentiated Mezosoic: *siltstone; dolomitic siltstone and limestone; silty dolomite, limestone, breccia and gypsum (Triassic) – fissile shale and siltstone; cherty and phosphatic dolomite and limestone; glauconitic shale and sandstone (Jurassic) – thick-bedded, fine- to coarse-grained, cherty sandstone interbedded with shale, siltstone and coal (Nikanassin and Kootenay Formations) – siliceous, calcareous sandstone; chloritic and feldspathic sandstone; carbonaceous and calcareous shale; shale and silty shale; some conglomerate; coal in central and northern Foothills; trachytic tuff, agglomerate in southern Foothills (Blairmore Group)* (Mz)

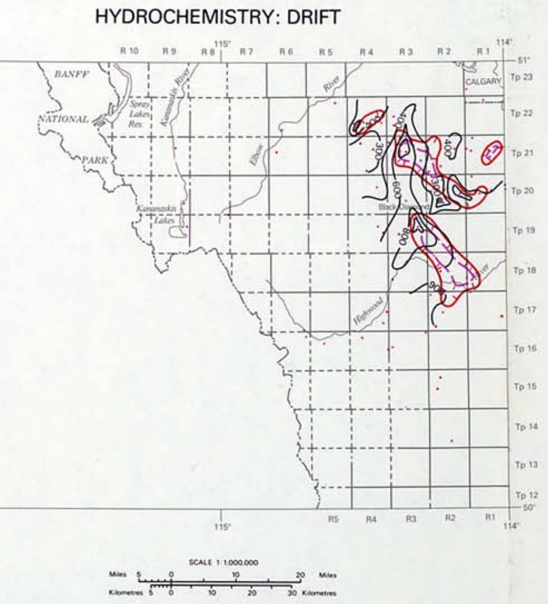
Upper Paleozoic: *argillaceous limestone and dolomite, in part cherty and stromatoporoidal, in part coarsely biostromal; nodular and calcareous shale; aphanitic to finely crystal-line limestone, dolomite-mottled limestone, and dolomite; bituminous shale (Upper Devonian) – fissile shale, siltstone, argillaceous limestone and cherty limestone; medium- to coarse-grained crinoidal limestone, cherty and dolomitic limestone; dolomite, cherty dolomite, anhydrite, shale and sandstone (Mississippian) – thin- and thick-bedded quartzose sandstone phosphatic quartzose siltstone, silty and cherty dolomite, chert and cherty carbonate (Pennsylvanian Permian)* (Pzu)

Lower Paleozoic: *thick-bedded, quartzite and quartzose sandstone, with shale and limestone lentils (Gog Group) – thick-bedded dolomite and limestone; fine-grained, thick- to thin-bedded limestone and dolomite; calcareous and siliceous shales; local intraformational conglomerates (Middle and Upper Cambrian) – limestone, shaly limestone and shale, local intraformational conglomerate; medium-bedded, siliceous dolomite; clean white quartzite (Ordovician) – medium-bedded fine-grained dolomite (Silurian)* (Pzl)

Rock unit boundary ....

Geology after R. Green (1970): Geological map of Alberta

HYDROCHEMISTRY: DRIFT



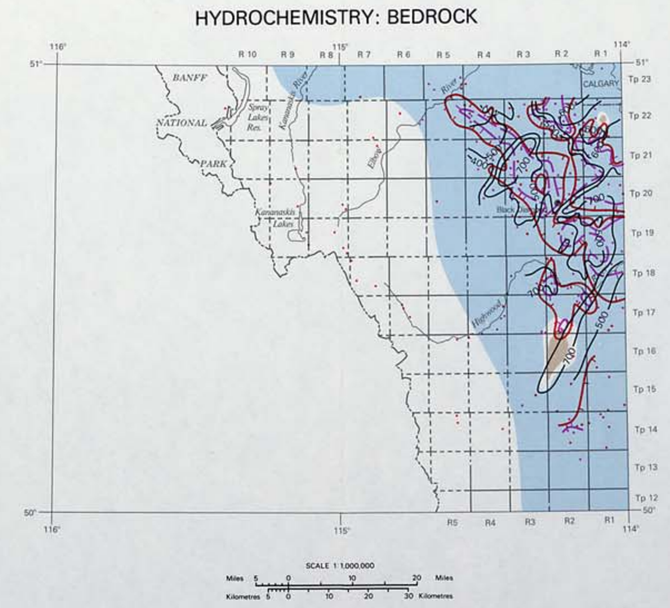
SCALE 1:1,000,000

LEGEND

Data control point marking location of a well with a chemical analysis ....
Data control point marking location of a spring with a chemical analysis ....
Total dissolved solids in parts per million, defined: 500
Isogram along which calcium + magnesium constitute 60 percent of total cations*; teeth indicate direction of lesser calcium + magnesium content, defined: ....
Isogram along which sodium + potassium constitute 60 percent of total cations*; teeth indicate direction of lesser sodium + potassium content, defined: ....

* determined on equivalents per million basis.

HYDROCHEMISTRY: BEDROCK



LEGEND

Data control point marking location of a well with a chemical analysis ....
Data control point marking location of a spring with a chemical analysis ....
Nonpumping water level contour in the bedrock (elevation in feet followed by metres in brackets) .... 3000(915)
Total dissolved solids in parts per million, defined: 500
Carbonate + bicarbonate constituting over 60 percent of total anions* ....
Sulfate constituting over 60 percent of total anions* ....
Isogram along which calcium + magnesium constitute 60 percent of total cations*; teeth indicate direction of lesser calcium + magnesium content, defined: ....
Isogram along which sodium + potassium constitute 60 percent of total cations*; teeth indicate direction of lesser sodium + potassium content, defined: ....

* determined on equivalents per million basis